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Editorial Comment

Intermediate Septal Accessory Pathways: Electrocardiographic Localization of Pre-excitation*

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The present study. Epstein and colleagues (1) in this issue of the Journal report on the electrocardiographic (ECG) characteristics of intermediate septal accessory pathways. I agree with many, if not all, of their conclusions and will restrict my comments primarily to the use of the QRS complex to predict the location of the ventricular insertion of accessory atrioventricular (AV) connections, first offering some general comments regarding ECG localization of accessory pathways that apply to most forms of pre-excitation, including intermediate septal pathways.

ECG for localizing accessory pathways. The ECG is a reasonably good noninvasive tool for localizing accessory pathways, assuming that only one such pathway is present and that a significant degree of ventricular pre-excitation exists at the time of the recording (2). In certain cases where "pseudoconcealed" pathways exist, these may be revealed by atrial pacing at increasing rates at locations close to the atrial insertion of the accessory pathway. The term "pseudoconcealment" implies that pre-excitation is present, even if not detected. The pattern of the ECG during ventricular pre-excitation is determined by both the location of the accessory pathway and the relative timing of the wave fronts arriving in the ventricle over the normal and accessory pathways. In certain patients the duration and degree of pre-excitation before the arrival of the impulse over the specialized conduction system are so slight that diagnosis of the presence of an accessory pathway is difficult and localization by ECG may be impossible. This is especially true of left lateral connections, inserting into the left ventricle in the region near its acute margin (near the origin of the obtuse marginal coronary artery). These sites are farthest from the sinus node and thus the relative arrival times of the normal and anomalous wave fronts may favor less pre-excitation and a greater component of ventricular activation programmed by the specialized ventricular conduction system (3). For reasons not fully understood, even efforts to alter this timing sequence by pacing close to the atrial insertion of the pathway may fail to produce obvious ECG evidence of pre-excitation in some patients. One reason may be the route over which the wave front approaches the atrial side of the connection. Certain input routes and wave front directions might facilitate accessory pathway AV conduction and others might not. This difference in input path and wave front direction might be more important in long, thin and more tenuous accessory pathways. For example, the patient may have variable degrees of ventricular pre-excitation or no pre-excitation at different times during sinus rhythm and no ventricular pre-excitation with atrial pacing very close to the pathway. This interaction between the accessory pathway, its location and geometry and the relative timing and direction of the input wave front might explain some of the enigmatic variations in pre-excitation encountered in some patients.

The pattern of atrial pre-excitation during orthodromic supraventricular tachycardia or ventricular pacing is helpful if P waves can be recognized in key ECG leads. Predominantly negative deflections in lateral chest leads suggest a left-sided concealed accessory pathway. Again, one must distinguish between a true concealed bypass where no evidence of ventricular pre-excitation is evident and pseudoconcealment in which the ventricular pre-excitation is present but subtle and evident only by pacing from the coronary sinus preoperatively or the left atrium intraoperatively during mapping.

Effect of pre-excitation on the QRS complex. A principle that has received very limited published discussion is that ventricular pre-excitation frequently affects more than just the first part of the QRS complex (4). Basically, it can affect the entire ventricular depolarization process and therefore the entire QRS complex and, in addition, the ST-T segment because the altered depolarization sequence and balance alter the repolarization phase (5). The effects on the middle and terminal QRS complex, as well as the ST-T segment, are not as obvious as the effects on the initial QRS complex (i.e., the delta wave). However, they may be recognized by comparing complexes in multiple leads during the presence and absence of pre-excitation in the same patient, either as a spontaneous occurrence preoperatively or as a result of accessory pathway ablation. This effect on the total QRS complex should not be surprising when one considers that both the ventricular activation sequence and repolarization reflect a balance of forces contributed by two merging wave fronts during the mid QRS complex and the absence of late wave fronts in the already pre-excited basal ventricular region, late in the terminal QRS complex. This is most apparent in patients with left ventricular pre-excitation in whom areas that would normally activate late do not contribute to the terminal QRS complex, changing S waves to R waves and vice versa in different leads. During the mid QRS complex, although not all regions are pre-excited, the presence of two wave fronts—either separated or after merging

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from different directions—results in a different balance of QRS forces and secondarily affects repolarization potentials.

Carried to the extreme for emphasis, studies in which pre-excitation was simulated and in which the timing of the pre-excitation could be varied relative to the timing of normal AV conduction demonstrated changes in the terminal QRS but not the initial or early QRS complex (4). In other words, it is possible for a region to be pre-excited relative to its regular activation time during normal depolarization and yet actually occur after wave fronts have reached the ventricular endocardium over the specialized ventricular conduction system. This is "delayed pre-excitation." I have observed this phenomenon in several patients and have mapped it in one patient with left ventricular pre-excitation at the time of ablative surgery. Thus, careful visual or possibly numeric differential analysis of the QRS complex and ST-T waves with and without pre-excitation in patients exhibiting spontaneous changes in activation, might be a useful technique for accurately predicting the site of accessory pathways. These principles could be extended to the interpretation of the ECG in patients with multiple accessory pathways. However, they would be more difficult to apply clinically without the assistance of a physical-mathematical model of simulated pre-excitation (6).

ECG patterns in intermediate septal accessory pathways. It is in this context that the electrophysiologist approaches interpretation of the ECG in the more complex forms of pre-excitation, such as intermediate septal pathways. Here the ECG pattern will depend on the relative timing of the anomalous and normal wave fronts as in all other forms of pre-excitation but, more specifically, to the balance of the pre-excitation wave fronts at three possible ventricular entry sites, which are: 1) the lateral-superior right ventricular conus region, 2) the right posterior ventricular septum, and 3) the posteroinferior right ventricle. Wave fronts 1 and 2 are involved in exclusive anteroseptal accessory pathways and wave fronts 2 and 3 in exclusively posterior septal accessory pathways. In an intermediate septal pathway, there is the possibility for all three wave fronts to be present and the initial forces will depend on the precise entrance time of these three components. This relative timing also affects the instantaneous size of wave fronts as each increasingly occupies more area over time after entry. This timing and balance is influenced by multiple factors, such as those previously discussed, but primarily to the exact site of insertion of the intermediate septal pathways in relation to the anterosuperior and posteroinferior right ventricular walls. Thus, the ECG pattern would vary between the two patterns associated with anteroseptal and posteroseptal pre-excitation and several (more than two) intermediate forms would be anticipated. For example, the direction of the initial delta in the frontal plane leads will depend on whether the posteroinferior or the anterosuperior right ventricular wave front arrives first and by how much. If the posteroinferior wave front is earlier and builds sooner and is therefore larger during the first 30 ms of pre-excitation than the later anterosuperior wave front in the right ventricular conus, then negative forces will predominate in the inferior leads. This is because activation on reaching the inferior right ventricle breaks through inferiorly and spreads upward and anteriorly away from the inferior sites of breakthrough. If the anterosuperior right ventricular conus wave front is earliest, the predominant direction of activation in the frontal plane is downward, resulting in positive QRS forces or delta waves in inferior leads.

Therefore, the ECG in forms of intermediate septal pathways, as correctly suggested by Epstein et al. (1), should reflect the timing and balance of two widely separated pre-excitation wave fronts, one posteroinferiorly and the other anterosuperiorly in the right ventricle. V lead morphology is more difficult to account for because there are few detailed activation mapping data obtained from the septum in subjects with an intermediate septal pathway (7). However, the direction of the initial delta forces in the anterior precordial leads should be related to the timing or earlier predominance of the septal wave front, which propagates from anterior to posterior and right to left. Its precise timing and size in relation to the two other wave fronts will determine whether the initial delta forces are positive, negative or biphasic in the anterior precordial leads and, in addition, whether the transition occurs between leads V_1 and V_2 or between leads V_2 and V_3.

Finally, although Epstein et al. (1) accurately address the issue of predicting the location of intermediate septal pathways, certain complexities related to the mechanisms discussed in this comment are meant to suggest that more data correlating the ECG pattern with details of the timing and distribution of ventricular and septal wave fronts and repolarization potentials, and with the sites of atrial and ventricular insertions and geometry of accessory pathways, are needed for ultimate resolution of these issues and accurate prediction of accessory pathway location.

References

1. Epstein AE, Kirklin JK, Holman WL, Plumb VJ, Kay GN. Intermediate septal accessory pathways: electrocardiographic characteristics, electrophysiologic observations and their surgical implications. J Am Coll Cardiol 1991;17:1570–8.
2. Lindsay BD, Crossen KJ, Cain ME. Concordance of distinguishing electrocardiographic features during sinus rhythm with the location of accessory pathways in the Wolff-Parkinson-White syndrome. Am J Cardiol 1987;59:1093–102.
3. Boineau JP, Moore EN, Spear JF, Sealy WC. Basis of static and dynamic electrocardiographic variations in Wolff-Parkinson-White syndrome. Am J Cardiol 1973;32:32–45.
4. Moore EN, Spear JF, Boineau JP. Electrophysiological studies on pre-excitation in the dog using an electronically simulated atrioventricular bypass pathway. Circ Res 1972;31:174–85.
5. Spach MS, Barr RC, Lanning CF. Experimental basis for QRS and T wave potentials in the WPW syndrome: the relation of epicardial to body surface potential distributions in the intact chimpanzee. Circ Res 1978;42:103–18.
6. Lorange M, Gulrajani RM. Computer simulation of the Wolff-Parkinson-White preexcitation syndrome with a modified Miller-Geselowitz heart model. IEEE Trans Biomed Eng 1986;BME-33:862–73.
7. Boineau JP, Moore EN. Evidence for propagation of activation across an accessory atrioventricular connection in types A and B pre-excitation. Circulation 1970;41:375–97.